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Progress Report RSC 3018-3

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APPLIED REGIONAL MONITORING OF THE VERNAL ADVANCEMENT AND RETROGRADATION (GREEN WAVE EFFECT) OF NATURAL VEGETATION IN THE GREAT PLAINS CORRIDOR

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In cooperation with:

Texas Agricultural Experiment Station
Texas A&M University
College Station, Texas 77843

November 1975
Type II Report for Period August 1975
October 1975

Prepared for:
Goddard Space Flight Center
Greenbelt, Maryland 20771

Contract No. NAS5-20796

TEXAS A&M UNIVERSITY
REMOTE SENSING CENTER
COLLEGE STATION, TEXAS

20540

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1.0 BACKGROUND & SUMMARY

1.1 Background

This 18 month long study, LANDSAT Follow-On Investigation 20540, is a regional expansion of the LANDSAT-1 investigation entitled "Monitoring the Vernal Advancement and Retrogradation (Green Wave Effect) of Natural Vegetation." The initial study was restricted to evaluating the discrimination of land use patterns and recognizing the phenological development at sites of known plant/soil composition. As expressed in the work statement of contract NAS 5-20796, three tasks are to be addressed during the course of this follow-on study. The first task involves the acquisition and analysis of satellite imagery and computer compatible data from natural vegetation systems in the Great Plains Corridor. The second task involves the acquisition of aerial photography, certain coordinated ground truth data, and environmental data in support of the satellite imagery and data. The third task relates to the correlation and analysis of satellite and support data for testing certain specific hypotheses important in evaluating the feasibility of an operational system for monitoring the status of natural vegetation in the Great Plains. The hypotheses to be tested are:

Hypothesis Number 1--Time is an important factor in the discrimination of broad landforms, soil associations, vegetation types and other natural resources features.

Hypothesis Number 2--The vernal advancement and retrogradation of vegetation (Green Wave Effect) can be discriminated on a regional basis using repetitive multi-spectral imagery.

Hypothesis Number 3--Vegetation systems parameters are adequately unique to provide a new information source for regional agri-business use.

To test the three hypotheses and to evaluate the application of LANDSAT data within the Great Plains region, the following specific objectives are to be addressed:

Objective Number 1--To develop a data analysis methodology that will facilitate the extension of regional satellite data from the LANDSAT follow-on.

Objective Number 2--To chart the vernal advancement and retrogradation of natural vegetation on a regional basis using LANDSAT data.

Objective Number 3--To record the phenological events and collect specific biological and environmental data using an effective test site network for ground observations.

Objective Number 4--To apply LANDSAT sensor measurements for identification of rangeland vegetation and soil types, measuring short-term and seasonal vegetation reflectance changes, and evaluating the impact of environmental conditions on dominant vegetation.

Objective Number 5--To evaluate the feasibility of using LANDSAT-type data, in conjunction with geographic and climatological parameters for modeling a range forage index and indexes of plant growth conditions.

1.2 Summary

During the quarter a tentative approach based on "response zones" was developed for use in rangeland vegetation condition monitoring. The response zones will be defined through integration of climatic and physiographic factors that affect the growth response of the vegetation. After development and testing is completed response zones for the GPC sites will be delineated and range feed condition maps generated from LANDSAT MSS data.

Ground truth data collection was completed during this reporting period. A summary of ground and LANDSAT data dates is given.

On September 23 and 24, 1:8000 scale color IR photography was acquired in 10 mile long strips centered on the ETSA ground data sampling locations. These photos

will be used to stratify the sampling locations so that comparable secondary sites can be selected for LANDSAT MSS data extraction.

Ground data that have been received from the GPC sites have been keypunched and summarized by computer. Some ground data had not been received by the end of the quarter.

LANDSAT MSS band 5 images that have been received have been evaluated for cloud cover over test sites. Retrospective product orders for CCT's have been placed with the EROS Data Center based on these evaluations.

Generalized soils maps have been acquired for all but two counties in the ETSA. Work was initiated, utilizing the maps, on a "consolidated soil type map" for the ETSA. This map will be used in delineating response zones.

Improvements in the accuracy of isoline contouring of parameters over the ETSA were realized by reducing the area to be contoured to the minimum size required to contain the data points and still cover the ETSA. This eliminates most of the undefined boundary areas to which the contouring routine extrapolated.

Three notable items were included under problem areas. The ASCS LANDSAT imagery account will definitely be exceeded, as suspected in a previous quarterly report.

TAMU has stopped the standing order entirely, and previously had cut the standing order in half, in an attempt to curtail spending on the account as much as possible. Even so the estimated overrun will be approximately $1800 by the end of the contract period.

A long delay was experienced in receiving the NASA high flight microfilm. Microfilm was received in late August and September for flights flown in June. Corresponding delays in receiving imagery for analysis resulted.

Conflicts between fall semester coursework for project staff and ground data collection requirements caused a reduction in the amount of ground sampling accomplished in the ETSA during the one fall sampling period. Of 17 primary sampling sites three were not visited in order to minimize travel time in the ETSA. Each of the three sites was similar to another site sampled in the standard manner, however, so the effect of the decreased sampling was also minimized.

A major paper was presented at, and will be published by, the Tenth International Symposium on Remote Sensing of Environment. D. W. Deering made the presentation in October at the Ann Arbor meeting.

1.3 Organization of the Report

The body of this Type II progress report is organized along the lines suggested in the contract statement of work. Section 2 (Accomplishments and Problem Areas) discusses details of the approach taken on this project and the tasks undertaken during the quarter for both data acquisition and analysis. It also delineates problems encountered and the effect they had on project and accomplishments expected to occur during the next quarter.

Section 3 (Significant Results, Publications and Presentations) relates significant results obtained and lists publications and presentations distributed during the quarter. Section 4 (Funds Expended and LANDSAT Data Status) presents the total expenditures during the quarter towards this project from three sources: TAMU contract funds; TAMU matching funds; and NASA high flight photography and LANDSAT data accounts at both the EROS Data Center and the ASCS Aerial Photography Field Office. The LANDSAT data expenditures are treated separately from the others and in the manner specified by the contract. Section 5 (Aircraft Data Usage) describes the ways in which aircraft data supplied by NASA have been utilized in the project activities.

2.0 ACCOMPLISHMENTS AND PROBLEM AREAS

2.1 Accomplishments During the Reporting Period

2.1.1 Approach to Development of ETSA Feed Condition Mapping

The basic project approach utilizing the Great Plains Corridor test sites in the development and testing of techniques for monitoring rangeland vegetation conditions on a regional basis was described in the Type II, No. 1 progress report (RSC 3018-1, September 1975). A 6.25 million hectare square area in north central Texas and southern Oklahoma was selected as the primary test site for extensive ground data collection for model testing and data processing technique evaluation. This area is called the Extended Test Site Area or ETSA.

During this reporting period a tentative approach for developing the rangeland vegetation condition monitoring capability using the ETSA was outlined. The basic approach centers on the concept of what will be called "response zones". These response zones will be defined through the integration of climatic and physiographic factors that effect the growth response of the vegetation. The development and testing of the green biomass estimation (and other) model(s) will be related to these response zones.

The following steps outline the general procedure for this analysis phase:

1) Develop climatic and physiographic parameter maps in the form of overlays to define the response zones.
2) Summarize the ground data to develop biomass "coefficients" by response zones.
3) Produce a green biomass contour map from the sampling location ground data.
4) Calculate the green biomass estimate for the ground sampling locations from the current TVI6 estimation model and produce contour map.
5) Evaluate the response zone influences.
6) Develop green biomass estimation models to account for response zone differences (if any).
7) Use secondary (selected from vegetation map–no ground data) sites from each response zone (assuming that there are response zone influences) and calculate the green biomass for these from LANDSAT data using the adjusted models incorporating weather influences (Figure 2-1).

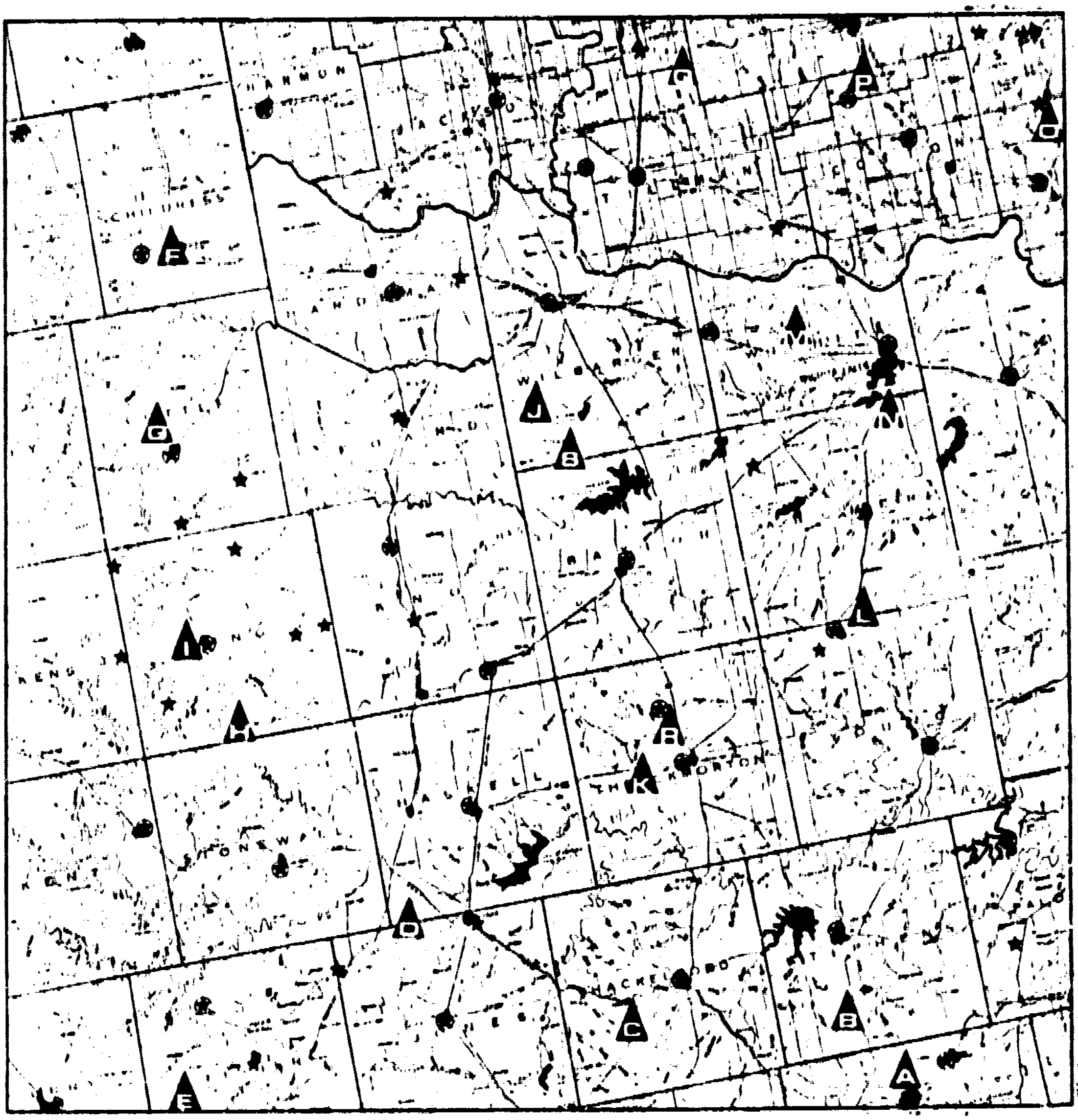


Figure 2-1. Location of the 61 weather stations (stars) within the ETSA from which data will be used to adjust LANDSAT data estimates of vegetation conditions. Also shown are the permanent sampling locations (lettered triangles).

8) Generate a green biomass contour map using these secondary site data.

9) Evaluate all steps for essentiality and develop a stepwise procedure for estimating range feed conditions.

10) Prepare these feed condition maps for several dates through the growing season.

The factors to be considered for development of the response zones are as follows:

1) Elevation - 25 meter contour intervals for overlays.

2) Soils - consolidated soil types (See Figure 4-8 of Final Report initial GPC Project) manual grouping from soil association maps.

3) Phenological Index - 2 day contour intervals (based on Hopkins Bioclimatic Law).

4) Climate

   a) Precipitation - average annual in 25mm increments.

   b) PET (potential evapo-transpiration) - in 25 mm increments.

   c) Ppt/PET - 0.1 increments.

   d) Each of the above a-c, by months.

Following successful completion of technique development and evaluation for the ETSA, response zones will be delineated for the GPC Test Areas. The procedure will be tested and ultimately range feed condition maps employing secondary sites within the Test Areas will be generated using LANDSAT MSS data.

2.1.2 Project Tasks Accomplished

Ground truth data collection was completed by the end of this reporting period for the Extended Test Site Area and the seven follow-on project test sites. Table 2-1 summarizes the dates on which ground measurements were acquired and the corresponding dates of LANDSAT coverage at each of the GPC test sites.

Exceptionally good weather prevailed throughout north central Texas and southern Oklahoma in mid-to-late September. Consequently, ground data were collected at the established ETSA sampling locations just immediately prior to the scheduled October 1 & 2 LANDSAT-2 overpass period. Weather conditions were excellent for these two overpass dates as well.

On September 23 and 24 medium scale (1:8,000) color infrared aerial photography was acquired along 10 mile long north to south flight lines centered on the sampling locations. These photos are necessary for the

Table 2-1. Dates of Ground Data Acquisition and LANDSAT Coverage.

Test Site	Ground Data	LANDSAT Overpass*	
ETSA	June 17-27	6-15&16-75	(2)
	July 21-Aug. 2	7-21&22-75	(2)
	Sept. 26-29	10-1&2-75	(2)
Throckmorton	March 7	3-8-75	(1)
	April 4	4-4-75	(2)
	April 23	4-22-75	(2)
	May 9	5-10-75	(2)
	May 28	5-28-75	(2)
	June 6	6-6-75	(1)
	June 16	6-15-75	(2)
	July 3	7-3-75	(2)
	July 21	7-21-75	(2)
	August 8	8-8-75	(2)
	August 25	8-26-75	(2)
	October 1	10-1-75	(2)
Woodward	June 13	6-16-75	(2)
	July 22	7-22-75	(2)
	October 2	10-2-75	(2)
Chickasha	June 6	6-6-75	(1)
	June 26	6-24-75	(1)
	July 31	7-30-75	(1)
	October 1	10-1-75	(2)
Hays	May 23	5-21-75	(1)
	July 14	7-14-75	(1)
	Sept. 24	9-24-75	(1)
Sand Hills	May 14	5-14-75	(2)
	June 1	6-1-75	(2)
	July 16	7-16-75	(1)
	Sept. 17	9-17-75	(2)
Cottonwood	June 1	6-1-75	(2)
	June 19	6-19-75	(2)
	July 26	7-25-75	(2)
	August 29	8-30-75	(2)
Mandan	June 3	6-2-75	(2)
	June 20	6-20-75	(2)

*Number in parentheses denote whether LANDSAT 1 or 2.

stratification of the sampling locations to enable accurate extraction of LANDSAT MSS data that correspond with the areas sampled on the ground. They will also be used in a multistage approach to detailed vegetation mapping in the ETSA and in selecting the secondary sites for vegetation condition mapping from LANDSAT data.

The Throckmorton test site has now been sampled in conjunction with 12 LANDSAT overpasses from March 7 through October 1. Five of the six more northerly test sites were sampled for ground data three or four times as scheduled in the late spring, early summer and late summer to early fall. Ground data were collected only when weather conditions during satellite overpass appeared to be good. At Mandan data were collected on two dates in late spring only.

The ground data that have been received from the test sites have been keypunched and summarized by computer, but all field data have not been received by the end of this reporting period.

Standing order Band 5 black-and-white LANDSAT-2 imagery products received to date from the ASCS Western Aerial Photo Lab total 102. Cloud cover evaluations relative to test site coverage have been made on them. Based on these evaluations retrospective product orders have

been placed to the EROS Data Center for computer compatible tapes and color composite imagery.

Topographic maps at 1:250,000 scale were acquired for the northern GPC test for use as an input for defining the response zones discussed in the previous section.

Generalized soils maps were acquired from the Soil Conservation Service for each county in the Extended Test Site Area, with the exception of two counties in Oklahoma, which did not have such maps readily available. Work has been initiated utilizing these maps to develop a "consolidated soil type map" for the ETSA. This map will be used as an input in the development of the response zones for the analysis phase of the investigation.

The development of computer aided material and overlays generated by computer is progressing according to schedule. The approach to development of the final output product (level contouring) had been divided into three steps defined as follows:

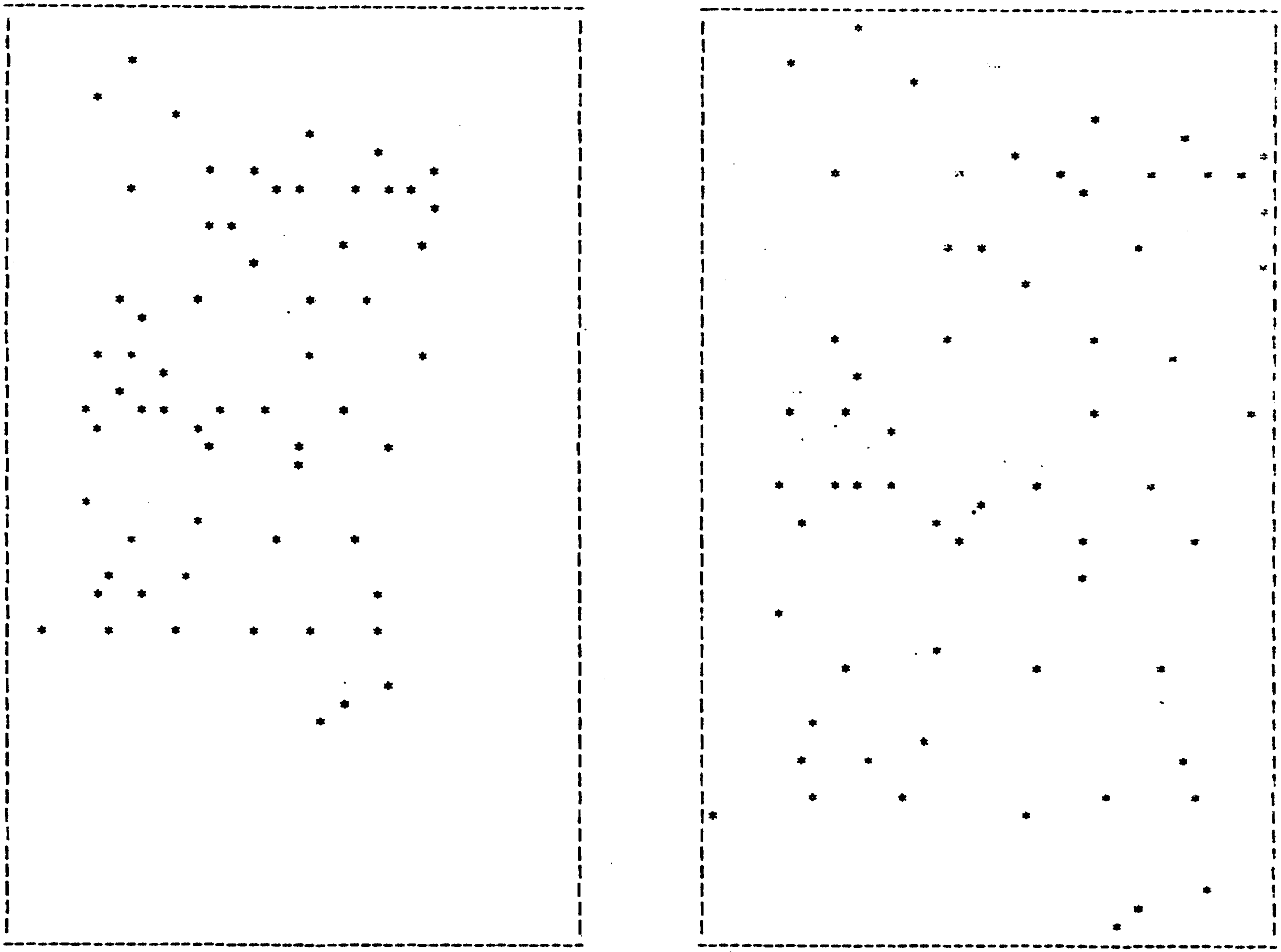
1) The mapping of points known in UTM (Universal Transverse Mercator) grid coordinates such as the weather stations or the soil sampling locations in the ETSA into an X-Y coordinate system with the two independent variables (X-Y) and a third dependent variable (F(X,Y)) representing precipitation or any desired feature such as green biomass.

Later the development of the dependent variable may be a step in itself as in the case of green biomass which is a combination of many pertinent facts.

2) The resulting sparse matrix (X-Y GRID) is then put through a spline fitting routine which interpolates between the known points (F(X,Y)) and determines a function that best defines the surface through which all dependent points pass.

3) With the function defined for the given area, a filled matrix (with all points defined) is then passed to a final program that does the level contouring producing the final product.

During this reporting period, the first step was modified to enhance the final product. It was found that when the sparse matrix had no points defined for a small area such as the case of the edges (see Figure 1, left), the resulting function calculated in step two and thus, the final product was affected noticeably. It was decided to expand the corner points in the sparse matrix out to the edges and ratio the other points accordingly (see Figure 1, right). The improvement of the function generated by this sparse matrix over the previous matrix was noticeable.



The process by which UTM (Universal Transverse Mercator Projection) is changed into an X-Y coordinate is demonstrated here. The right graph shows the expanded sparse matrix.

The sparse matrix is then put through a statistical analysis package (SAS) which is available to users at Texas A&M University. The package itself was developed by the Department of Statistics at North Carolina State University. It consists of many subroutines with varied uses. One of these, a Regression Analysis Routine that derives beta values or coefficients for n^{th} order equations. A surface thus defined passes through specific points supplied to the program. These points are the individual points defined in the sparse matrix. Along with the beta values statistical analysis of the significance of each coefficient and the closeness of the fit of the function to the given points is calculated. The program then goes back with the function and predicts the dependent variable for each of the given x and y values. The resulting value for each F(x,y) is not always identical with the given F(x,y), they are statistically very close, however. Work is continuing to make these differences as small as possible by making sure the dependent values are ordered as well as possible.

2.2 Problem Areas

Completion of the ground data collection phase of the investigation posed no major problems but one

aspect should be recognized. First, the period for fall-ground data collection in the ETSA had to be compressed. All of the employees experienced in field sampling the ETSA began their coursework for the fall semester and consequently dropped back to part-time employment. In order to minimize out-of-class time a subset of the total sampling locations that had been established was selected to provide an adequate measure of the range of conditions existing across the region. Sampling locations B, C, E, F, H, I, M, N, O, and Q were sampled in the standard manner. In addition, locations A, G, I, and P were quickly visited and the general vegetation conditions were documented by photographs. Of the 17 primary locations, only three were not visited.

The first roll of microfilm containing copies of the early June NASA high flight aerial photography was received on August 22. The second roll was received on August 29, and the third roll on September 29. A retrospective order for duplicate 9" x 9" transparencies for coverage of the ETSA flight lines only was placed on September 23. These products had not been received by the end of this reporting period. Many project activities, such as final resource map preparation and secondary site selection in the ETSA cannot be properly completed until these photos are received.

Concern regarding possible overrunning on the ASCS LANDSAT imagery account were voiced initially in the Progress Report RSC 3018-1. Costs to acquire color composite images and other image products have now been estimated through project completion and budget status has been reviewed. In order to limit cost overrun as much as possible a request was made by TAMU to cancel the LANDSAT standing order with ASCS. This request is due to the fact that field data collection has ended and further LANDSAT data will not always be useful. Images that are desired will be retroactively ordered.

A review of the requirements for CCT's, aerial photography and LANDSAT imagery indicates that the deposited funds at ASCS will not be adequate for the required aerial photography and LANDSAT imagery. However, excess funds deposited at EROS for CCT's might be utilized to augment the deposit at ASCS to cover the overrun. A formal letter requesting this fund transfer is being submitted to the contracting officer.

The following table lists the planned expenditures for material yet to be acquired on the contract.

	Balance in Account on 12/1/75	Planned Expenditure	Additional Funds Needed
CCT's	$24,000	$20,000	[$4,000]
Aerial Photography	[74]	2,058	2,200
LANDSAT Imagery	$964	2,500	1,500

2.3 Recommendations

Since the analysis phase of the project is just beginning, no recommendations based on project results can be made.

2.4 Accomplishments Expected During the Fourth Quarter

Ground truth data will be keypunched for computer processing and will be statistically analyzed and summarized.

Acquisition and compilation of weather data obtained by the 61 ETSA weather stations during the 1975 growing season will be initiated.

NASA high flight aerial photography will be utilized in a multistage approach to a more detailed vegetation mapping effort for the ETSA. The ETSA vegetation will consequently be characterized on a LANDSAT image base. The secondary sites will be determined utilizing this information.

Aerial photo duplicates of the remaining GPC test areas will be ordered for later vegetation mapping by a similar process.

Standing order LANDSAT images and LANDSAT browse facility microfilm of LANDSAT's 1 & 2 coverage will be evaluated relative to ground data that were collected, and retrospective product orders for images and CCT's will be placed.

The consolidated soil type map of the ETSA will be completed and prepared as an overlay for response zone determination. Preparation of additional overlays necessary for this procedure as described in Section 2.1.1 will be initiated.

Emphasis in the development of the computer related products will be placed on the following. In the generation of the level contours, the UTM map system is used as a basis for the operation of the final product. The UTM system is ordered and roughly parallel with latitude and longitude lines. All maps made thus far of the ETSA have been created to correspond with the satellite images which are skewed off the polar plane of the earth by a few degrees. This means that the orientation of the two products is different. Solutions to the problem are being considered, either to translate the

matrix in step one of the computer development of the contours, or to make new maps that are not aligned with the satellite track. Software required to accomplish the desired mapping will be completed during the quarter.

3.0 SIGNIFICANT RESULTS, PUBLICATIONS AND PRESENTATIONS

3.1 Significant Results

During the third quarter no significant results were obtained from the analysis as the period was spent primarily completing data acquisition and processing data to forms appropriate for analysis. An approach for developing the rangeland vegetation condition monitoring capability was determined during this period, however, and portends to be significant during the next quarter. The approach centers on "response zones", defined through the integration of climatic and physiographic factors that effect the growth response of the vegetation. Testing of this approach through practice during the following quarter will be accomplished.

3.2 Publications and Presentations

A major paper and presentation was produced during the third quarter. D. W. Deering presented "Measuring 'Forage Production' of Grazing Units from LANDSAT MSS Data" at the Tenth International Symposium on Remote Sensing of Environment in Ann Arbor, Michigan in October. The paper, Texas Agricultural Experiment Station contribution TA12-188, will be published in the Symposium proceedings. The paper was co-authored by D. W. Deering, J. W. Rouse, Jr., R. H. Haas and J. A. Schell.

4.0 FUNDS EXPENDED AND LANDSAT DATA STATUS

4.1 Total Expenditures To-Date

Expenditures under this contract are divided here into three categories for the purpose of discussion. TAMU contract expenditures; those from TAMU matching funds; and NASA expenditures. The items considered under NASA expenditures as accountable directly to this project are those for LANDSAT imagery, LANDSAT CCT data and the high flight aerial photo on accounts set up with the EROS Data Center and the ASCS Aerial Photography Field Office. Table 4-1 gives the total expenditure for the quarter under each of the categories.

Table 4-1 in each of the two preceding quarterly progress reports (3018-1 and 3018-2) was in error. Amended tables for those periods are given below. The errors were the result of an omission of overhead charged on salaries and wages and miscalculation of expended matching funds. The reported figures in the quarterly reports therefore underestimated expenditures and overestimated the TAMU contract balance at the end of each quarter as well as underestimated matching fund expenditures.

Correction to Table 4-1 (Progress Report RSC 3018-1):

	Budgeted	Expended	Balance
TAMU Contract	\$97,000.00	\$11,314.35	\$85,685.65
TAMU Matching Funds	\$58,700.00	\$ 9,783.00 (ave./qtr.)	\$48,917.00

Table 4-1. Third Quarter Expenditures

	Total Budget	Balance Forwarded	Expenditures This Quarter	Balance
TAMU Contract	$97,000.00	$68,647.04	$23,315.08	$45,331.96
TAMU Matching Funds	$58,700.00	$39,134.00	$ 9,783.00 (Ave./Qtr.)	$29,351.00
NASA Data Accounts	$29,200.00	$28,126.00	$ 2,210.00	$25,916.00

Correction to Table 4-1 (Progress Report RSC 3018-2):

	Total Budget	Balance Forwarded	Expenditures this Quarter	Balance
TAMU Contract	$97,000.00	$85,685.65	$17,038.61	$68,647.04
TAMU Matching Funds	$58,700.00	$48,917.00	$ 9,783.00 (ave./qtr.)	$39,134.00

4.2 Data Status

Three data accounts have been established for this project. Both a LANDSAT imagery account (20540) and an aircraft imagery account (20540 AC) have been set up with the ASCS Aerial Photography Field Office. A LANDSAT CCT data account is in effect with the EROS Data Center. Table 4-2 lists the budgeted amount, the amount ordered, and that received for each account during the quarter.

Table 4-2. Data Expenditure Tabulation

Account	Value of Data Allowed	Balance at Start of Quarter	Value of Data Ordered	Value of Data Received	Balance at End of Quarte
ASCS LANDSAT Imagery (20540)	1800	926	369	240	686
ASCS Air-craft Imagery (20540AC)	2640	2640	2728	1370	1370
EROS CCT Data (GB0540)	24800	24600	600	600	24000

5.0 AIRCRAFT DATA USAGE

Three microfilm rolls containing copies of NASA high flight coverage of the Great Plains sites were received between August 22 and September 29, 1975. The microfilm frames concerning the ETSA were evaluated and a retrospective order for duplicate 9" x 9" transparencies of the ETSA flight lines was placed on September 23. These products had not been received by the end of the quarter. When received they will be used in such activities as final resource map preparation and secondary site selection.